

# **AMTD: Mirror Substrate Design Trade Study**

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# Trade Study

Using Arnold Lightweight Mirror Modeler tool, evaluate candidate primary mirror substrate and assembly designs.

Assembly is Substrate, Support Structure & Interface Geometry

## Evaluation Criteria

Mass	This Study
Thickness (volume)	This Study
First Mode Frequency (stiffness)	This Study
1.5 G Internal Stress	Future Study
Dynamic Launch Loads	Future Study
Thermal Deformation	Future Study
Thermal Time Constant	Future Study

This presentation is reporting on Substrate Trade Study only

# Current Mirror Substrate Trade Study

Evaluated four mirror architectures:

- 4 meter solid

- 4 meter lightweight closed back

- 8 meter solid

- 8 meter lightweight closed back

Maximize First Mode Frequency as a function of:

- Depth

- Face sheet Thickness

- Rib Thickness

- Radius of Curvature

Constraints:	4 m monolithic	8 m monolithic
Mass	< 720 kg	< 10,000 kg
Thickness	< 500 mm	< 500 mm

# Future Mirror Substrate Trade Study

We plan to expand the study to include:

Open Back Substrates

And study Performance Criteria as a function of:

Depth

Face sheet Thickness

Rib Thickness

Radius of Curvature

Material Choice

Material Property Variation

Mount Interface (3, 6, 9 point)

Backing Structure Design

# Design Process

Defining dimensions on left & check boxes for design elements

Outer Dia	<input type="text" value="4"/>	<b>Supports</b> <input type="radio"/> Each Segment <input checked="" type="radio"/> Whole Mirror	<b>DISPLAY GRID</b>
Inner Dia	<input type="text" value="0.8"/>		
Cell Width	<input type="text" value="0.22"/>		
Lip Inner	<input type="text" value="0.03"/>		
Segment Lip	<input type="text" value="0.03"/>	<input checked="" type="checkbox"/> Show Whole Grid	<b>DISPLAY MODEL</b>
Mirror Lip	<input type="text" value="0.03"/>	<input type="checkbox"/> Show Supports	<b>WRITE MODEL</b>
Num Rings	<input type="text" value="2"/>	<input type="checkbox"/> Show Fillets	<b>SAVE</b> <b>RESTORE</b>
Sgmt Span	<input type="text" value="1.5"/>	<b>MERGE NODES</b>	
Sgmt Gap	<input type="text" value="0.075"/>		
Merge Tol	<input type="text" value="0.016"/>		
Grid Zoom	<input type="text" value="1"/>		
Segment Shown	<input type="text" value="1"/>		
Srink Factor	<input type="text" value="0.05"/>		

<b>Boule Mapping</b>								
Grid Options	Optical	Reals	Core	Hexapod	Axial	Radial	Inertial Loads	Modal (PSD)
<input checked="" type="checkbox"/> Outer Sgmt Lip	<input checked="" type="checkbox"/> Isogrid Front	<input type="radio"/> Cell Level 0						
<input checked="" type="checkbox"/> Outer Mirror Lip	<input checked="" type="checkbox"/> Isogrid Back	<input type="radio"/> Cell Level 1						
<input checked="" type="checkbox"/> Inner Mirror Lip	<input type="checkbox"/> Backface Holes	<input checked="" type="radio"/> Cell Level 2						
<input type="checkbox"/> Circular Segment	<input type="checkbox"/> Core Projection							
<input checked="" type="checkbox"/> Circular Mirror	<input type="checkbox"/> Include Fillets							
<input checked="" type="checkbox"/> Seal Ring Outer	<input type="checkbox"/> Off Center Pattern							
<input checked="" type="checkbox"/> Seal Ring Inner	<input type="checkbox"/> No Backsheet							
<input checked="" type="checkbox"/> Seal Ring Mirror	<input checked="" type="checkbox"/> Central Hole							

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# Design Process

Specify “reals” or real constants used by Ansys

Arnold Lightweight Mirror Modeler (Ver 2.0.0.1)

Outer Dia: 4  
Inner Dia: 0.8  
Cell Width: 0.22  
Lip Inner: 0.03  
Segment Lip: 0.03  
Mirror Lip: 0.03  
Num Rings: 2  
Sgmt Span: 1.5  
Sgmt Gap: 0.075  
Merge Tol: 0.016  
Grid Zoom: 1  
Segment Shown: 1  
Sink Factor: 0.05

Supports  
☐ Each Segment  
☒ Whole Mirror  
☒ Show Whole Grid  
☐ Show Supports  
☐ Show Fillets

DISPLAY GRID  
DISPLAY MODEL  
WRITE MODEL  
SAVE RESTORE  
MERGE NODES

Boule Mapping  
Grid Options Optical Reals Core Hexapod Axial Radial Inertial Loads Modal (PSD)

r, 1	0.0025	Front Facesheet	<input checked="" type="checkbox"/> Show
r, 2	0.0025	Back Facesheet	<input checked="" type="checkbox"/> Show
r, 3	0.002	Front IsoGrid Web	<input checked="" type="checkbox"/> Show
r, 4	0.005	Outer Seal Ring	<input checked="" type="checkbox"/> Show
r, 5	0.005	Inner Seal Ring	<input checked="" type="checkbox"/> Show
r, 6	0.002	Core Web	<input checked="" type="checkbox"/> Show
r, 7	0.002	Back IsoGrid Web	<input checked="" type="checkbox"/> Show
r, 8	0.01	Front Outer Seg Lip	<input checked="" type="checkbox"/> Show
r, 9	0.01	Back Outer Seg Lip	<input checked="" type="checkbox"/> Show

Mirror Material  
☒ ULE  
☐ Zerodur  
☐ E6  
☐ Fused Silica  
☐ BK7  
☐ Silicon Carbide

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# Design Process

Core Specification has its own tab.

Core depth is total core thickness divided by number layers.

Front & back depths include facesheet thickness & pocket depth.

Arnold Lightweight Mirror Modeler (Ver 2.0)

Outer Dia: 4  
Inner Dia: 0.8  
Cell Width: 0.22  
Lip Inner: 0.03  
Segment Lip: 0.03  
Mirror Lip: 0.03  
Num Rings: 2  
Sgmt Span: 1.5  
Sgmt Gap: 0.075  
Merge Tol: 0.016  
Grid Zoom: 1  
Segment Shown: 1  
Sink Factor: 0.05

Supports  
☐ Each Segment  
☒ Whole Mirror  
☒ Show Whole Grid  
☐ Show Supports  
☐ Show Fillets

DISPLAY GRID  
DISPLAY MODEL  
WRITE MODEL  
SAVE RESTORE  
MERGE NODES

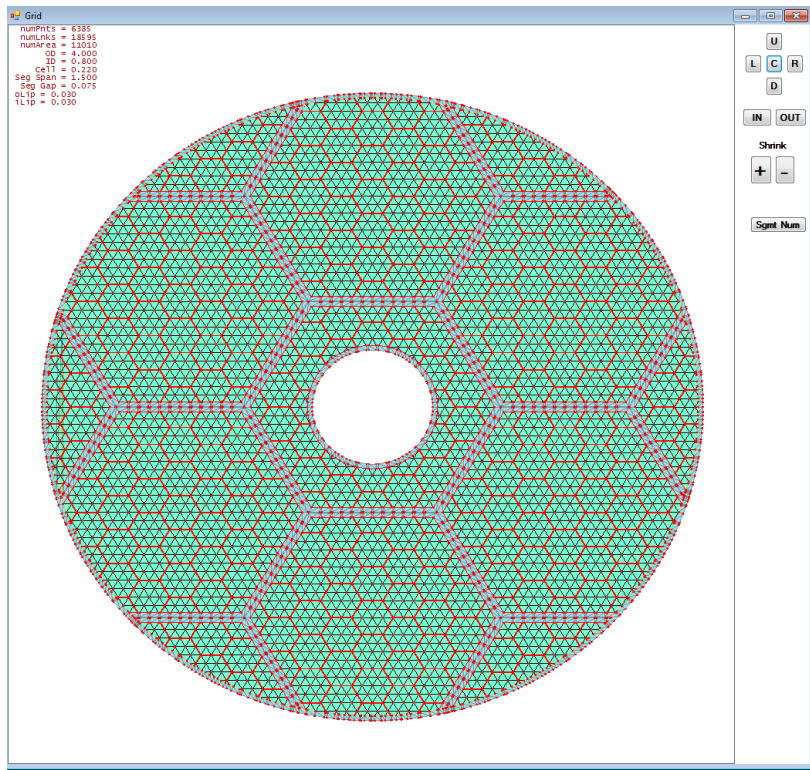
Boule Mapping  
Grid Options Optical Reals **Core** Hexapod Axial Radial Inertial Loads Modal (PSD)

Front Depth: 0.0175  
Core Depth: 0.375  
Back Depth: 0.0175  
Total Depth: 0.41  
Core Layers: 3  
CoreWeb Fillet Radius: 0.005  
IsoGrid Fillet Radius: 0.005

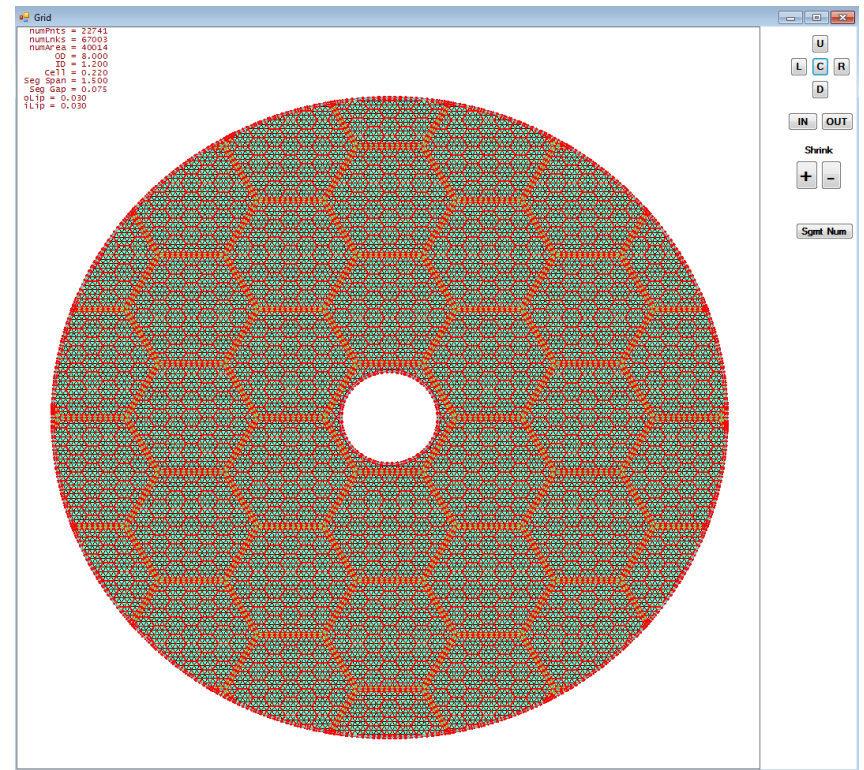
# Grid View

Grid view shows internal core segments, lips, cells, and isogrid

4 meter Design

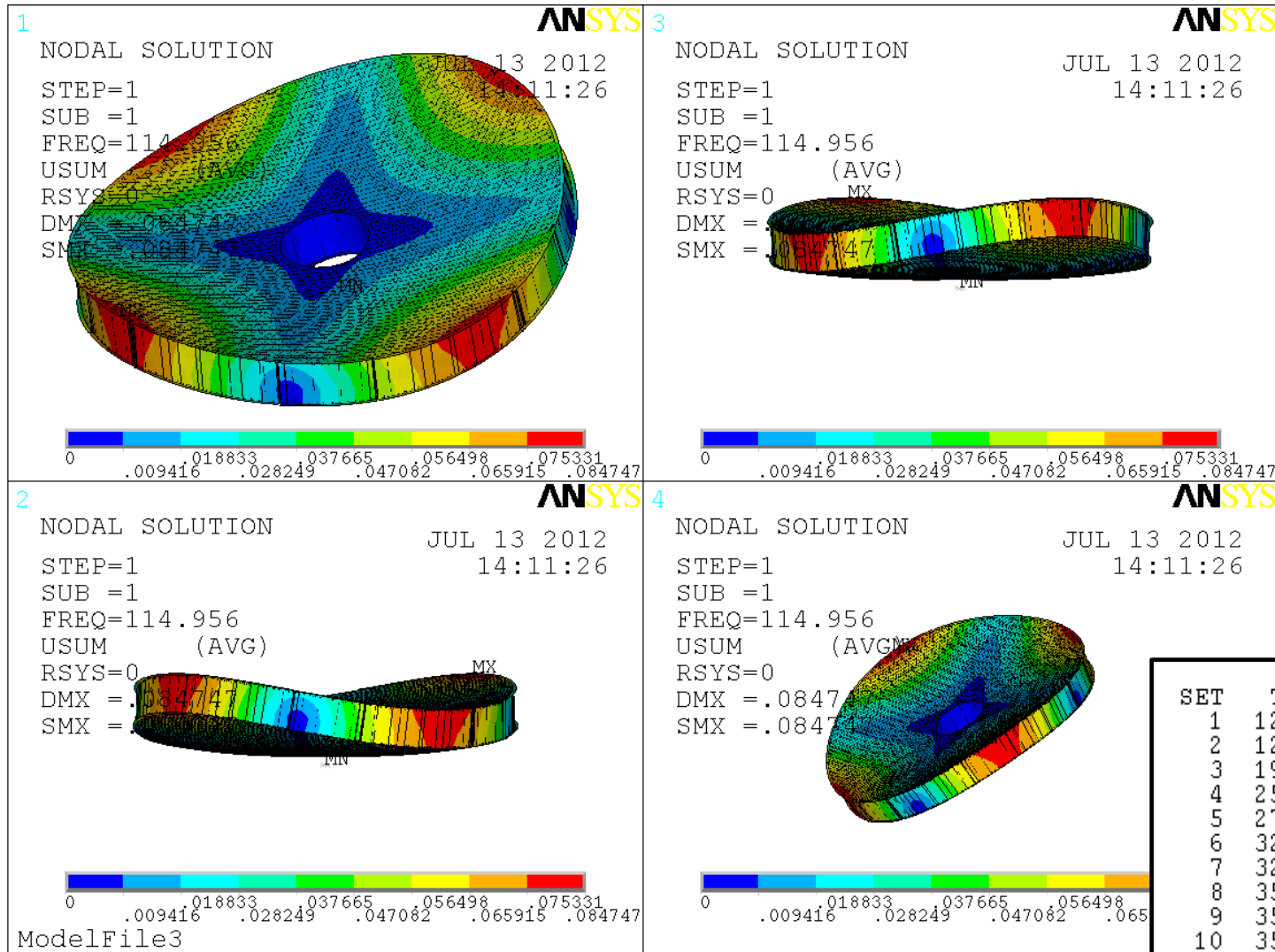


8 meter Design





# ANSYS performs Modal Analysis

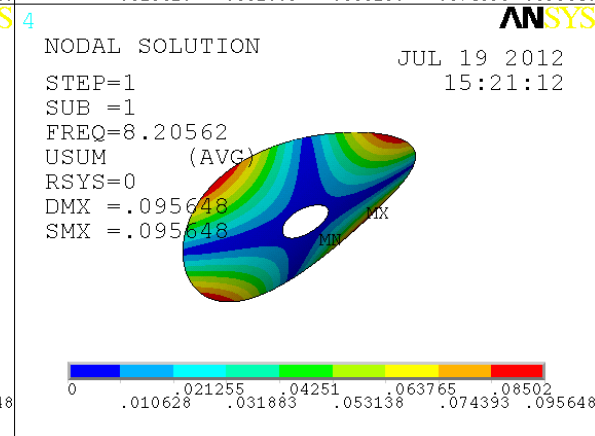
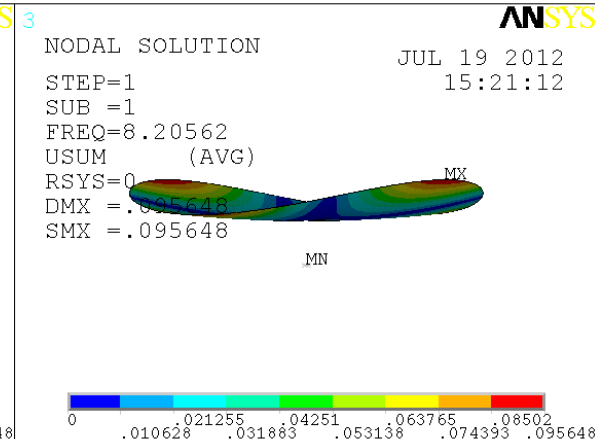
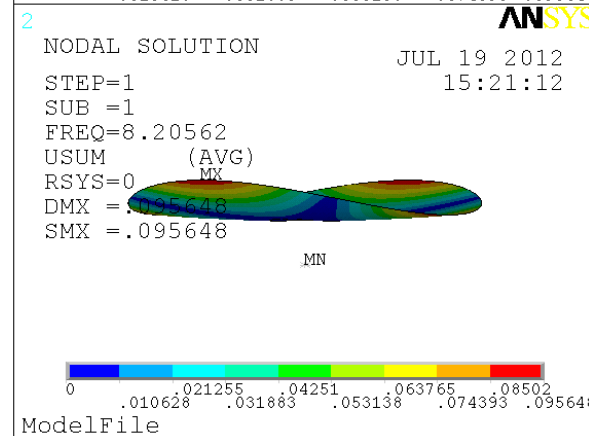
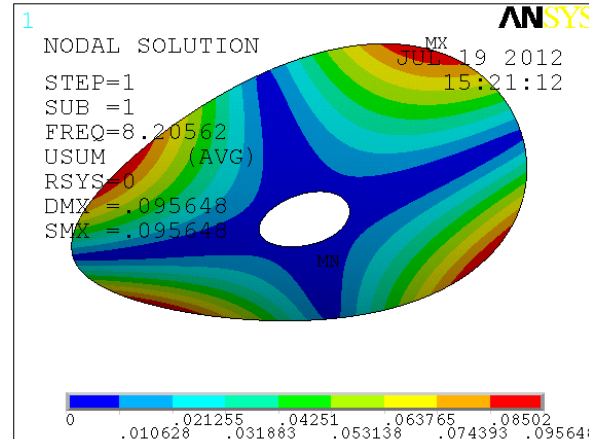


# Trade Study Concept #1: 4 m Solid

## Design:

Diameter 4 meters  
Thickness 22 mm  
Mass 595 kg  
First Mode 8.2 Hz

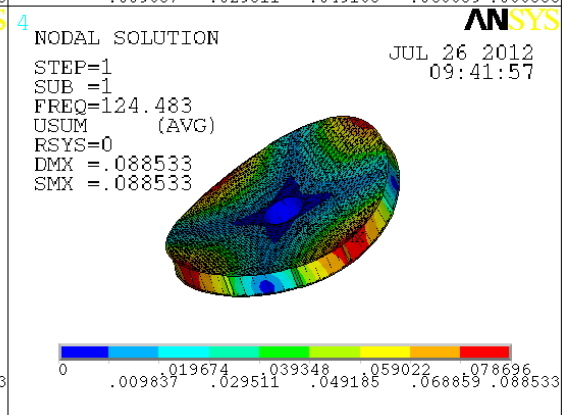
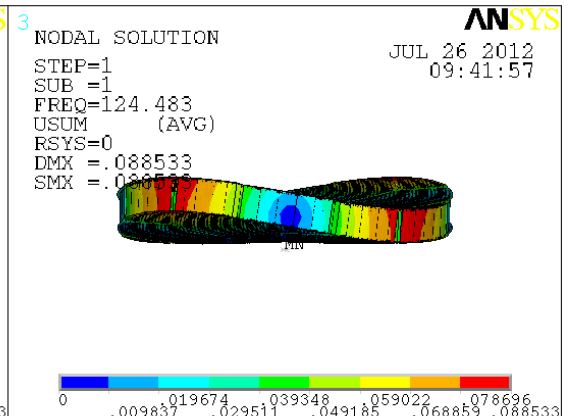
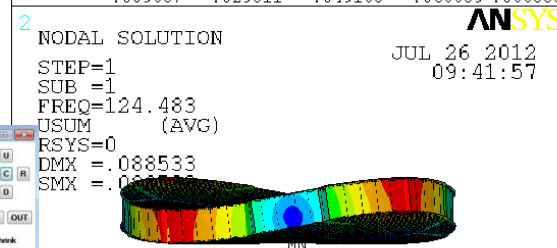
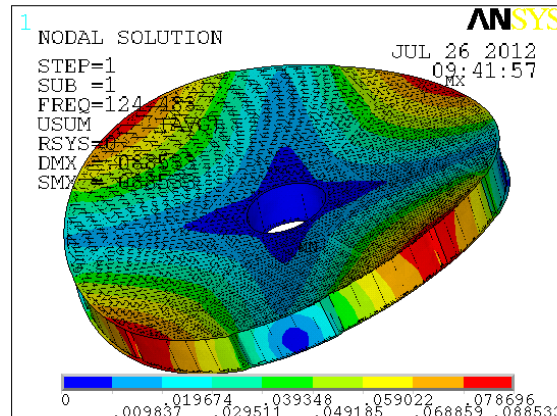
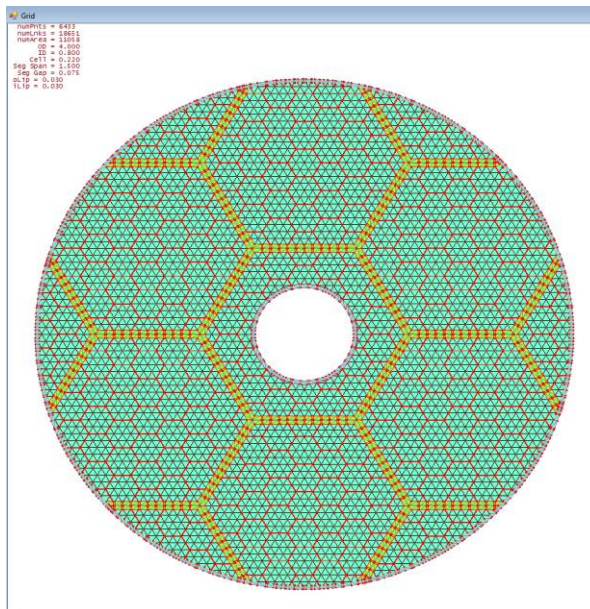
SET	TIME/FREQ
1	8.2056
2	8.2056
3	19.724
4	19.728
5	34.433
6	34.433
7	52.164
8	52.164
9	72.825
10	72.825



# Trade Study Concept #2: 4 meter Lightweight

## Design:

Diameter 4 meters  
Thickness 410 mm  
Facesheet 3 mm  
Mass 621 kg  
First Mode 124.5 Hz



SET	TIME/FREQ
1	124.48
2	124.77
3	199.39
4	257.85
5	275.88
6	321.22
7	321.60
8	350.07
9	350.08
10	350.33

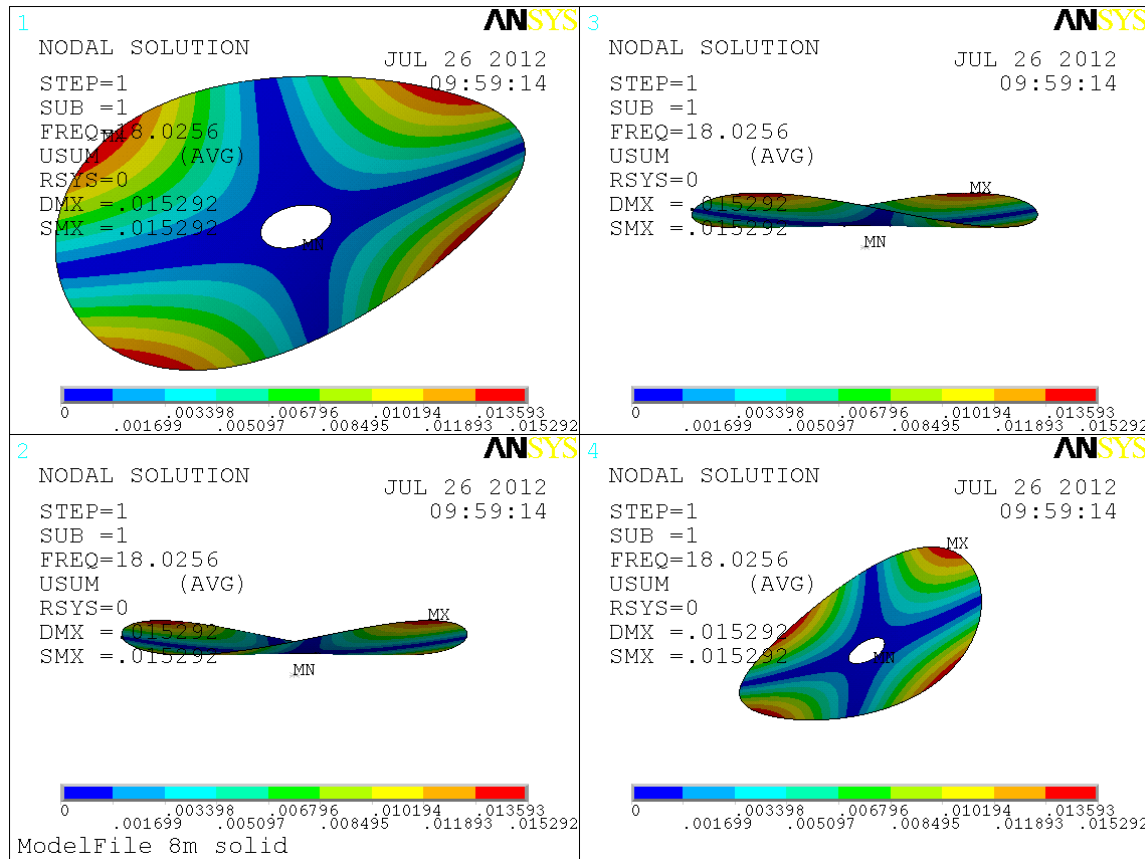
# Trade Study Concept #3: 8 meter Solid 22 MT

## Design:

Diameter 8 meter  
Thickness 200 mm  
Mass 21,800 kg  
First Mode 18 Hz

Same as ATLAST Study

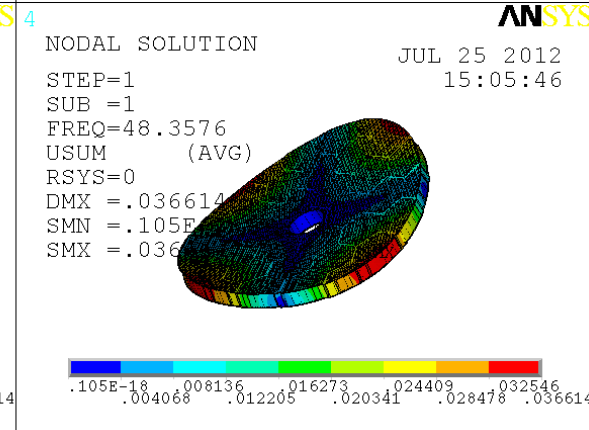
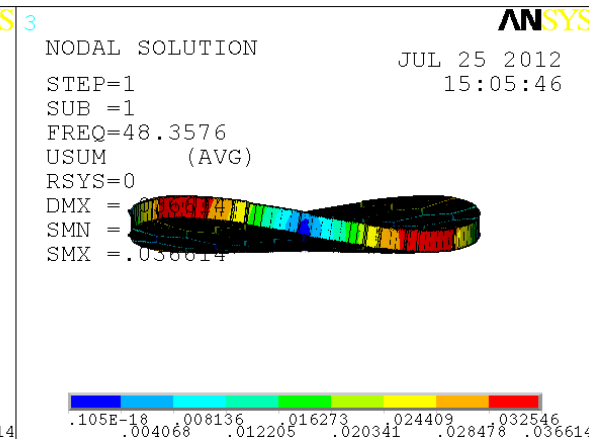
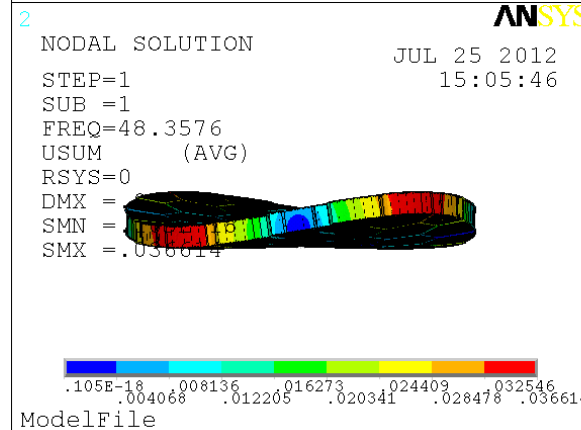
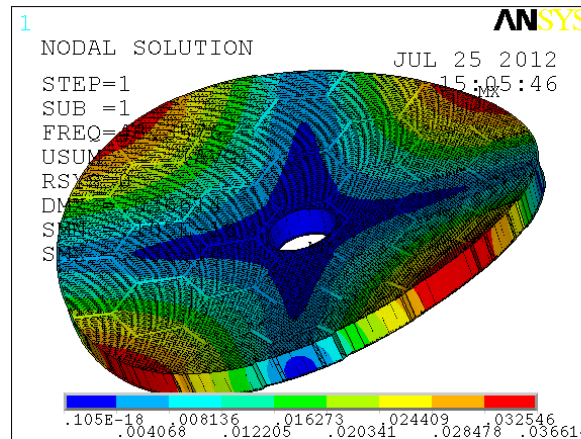
SET	TIME/FREQ
1	18.026
2	18.035
3	42.449
4	42.452
5	47.827
6	74.041
7	74.045
8	75.174
9	75.176
10	112.96



# Trade Study Concept #4: 8 meter Lightweight

## Design:

Diameter 8 meter  
Thickness 510 mm  
Facesheet 7 mm  
Mass 3,640 kg  
First Mode 48.4 Hz



# Parameter Trade Studies

4 meter

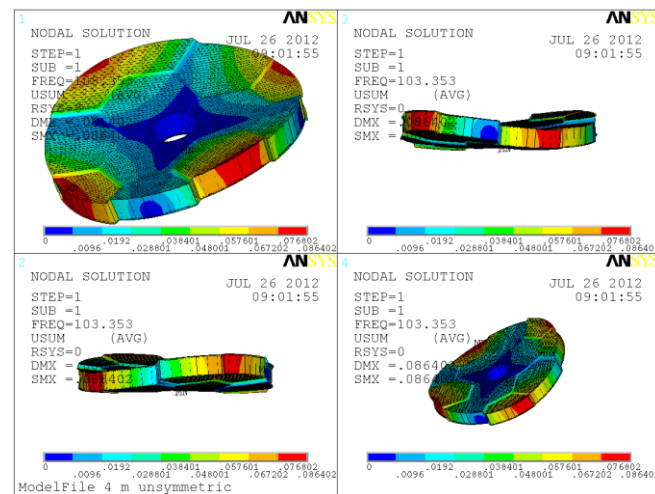
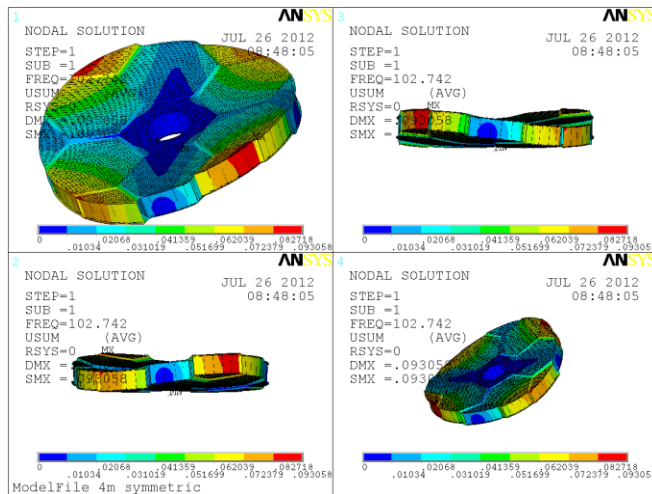
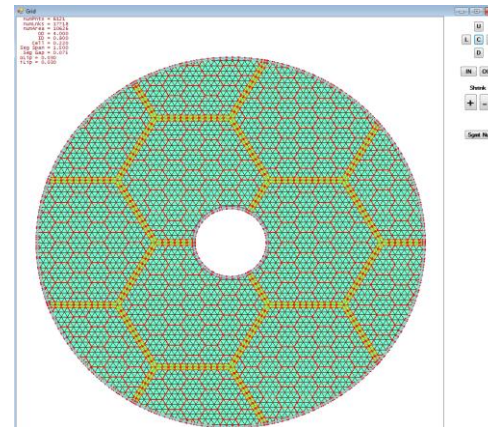
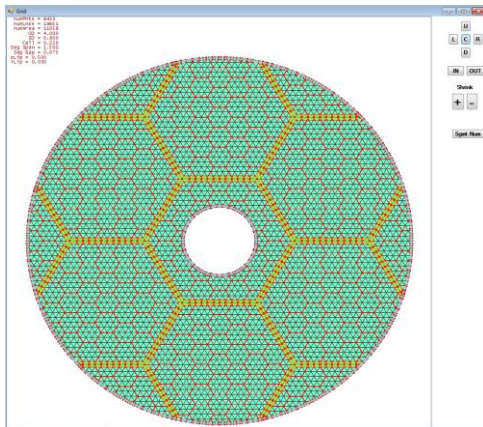


# Symmetric vs. Offset

For a 4 meter, 310 mm thick mirror substrate, there is no observable difference between symmetric and off-set

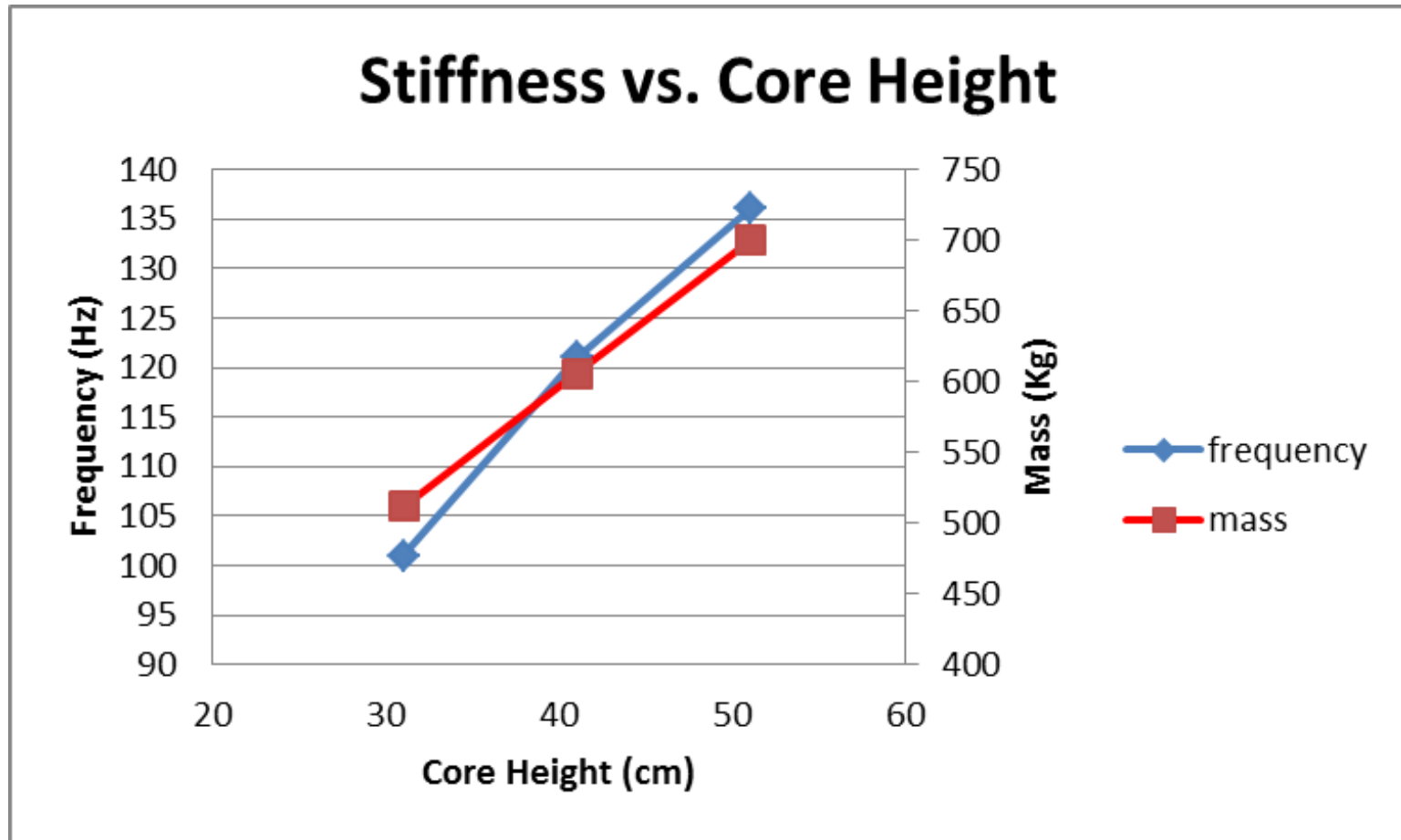
Symmetric (103 Hz)

Offset (103 Hz)



## 4 meter Stiffness & Mass vs Core Height

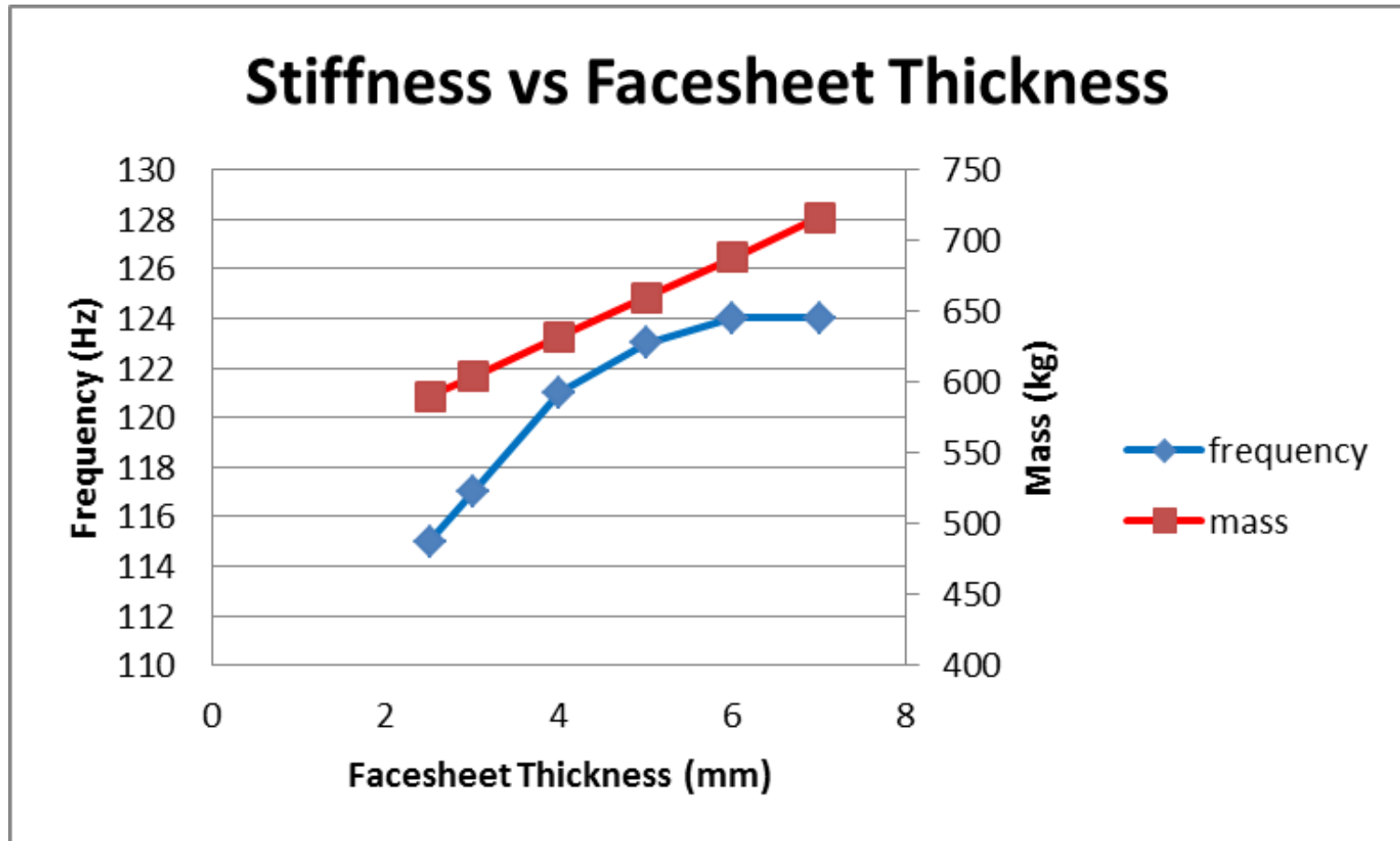
As expected, Core Depth has the greatest impact on stiffness; the deeper the Core the Stiffer and more Massive the Substrate.





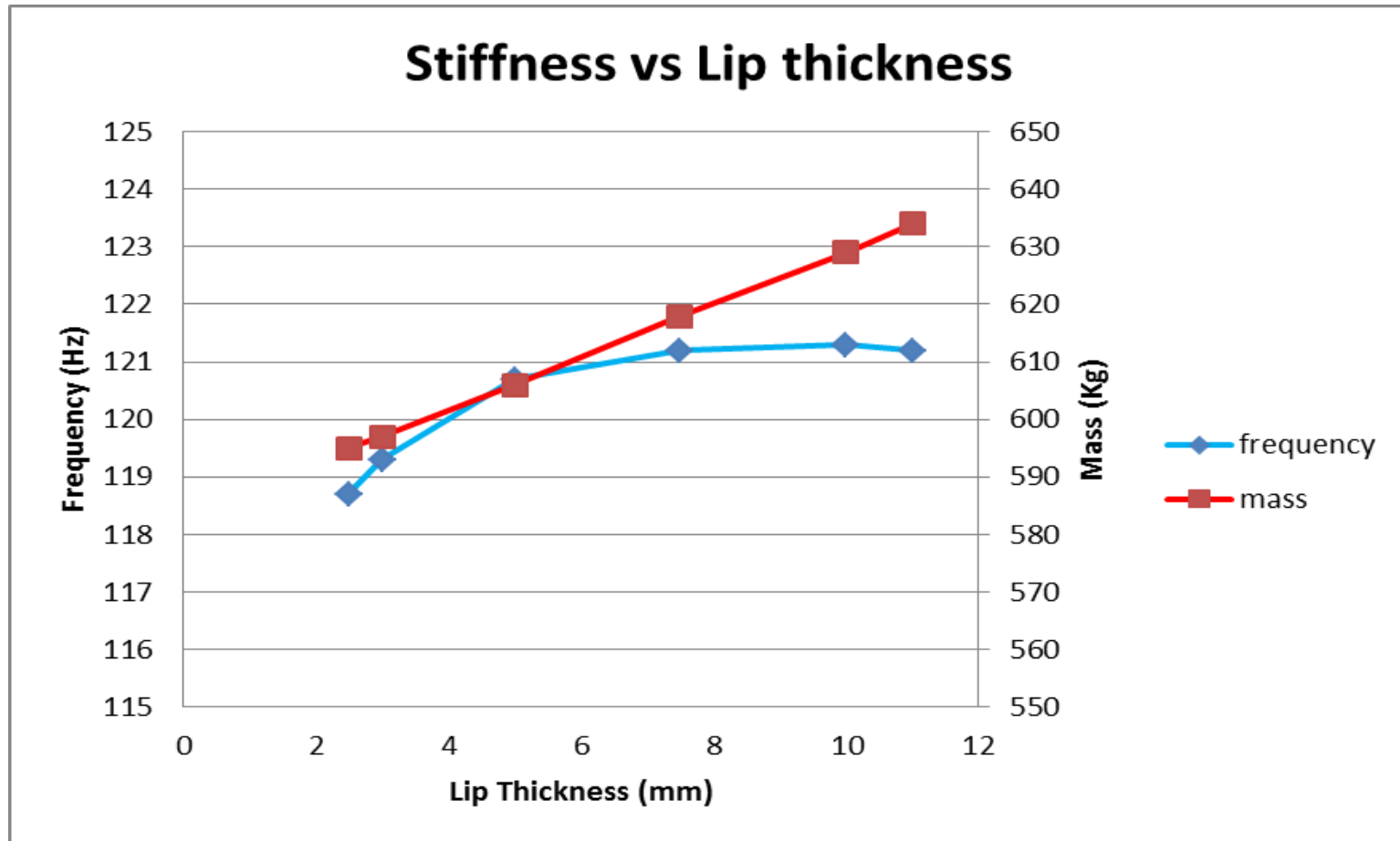
## 4 m Stiffness & Mass vs Facesheet Thickness

Increasing Facesheet thickness increases stiffness only to a point, then the stiffness decreases with additional thickness.



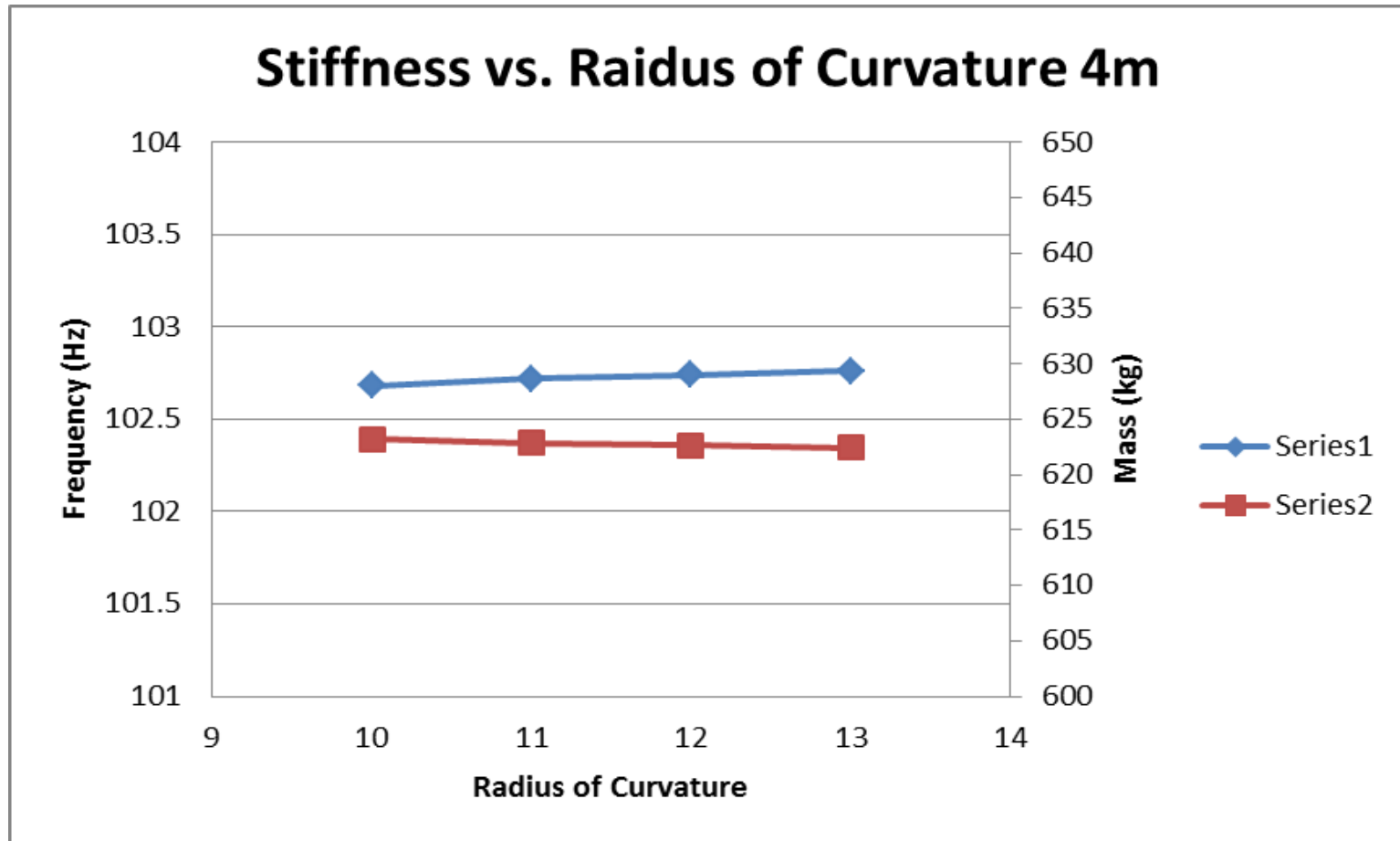
# 4 m Stiffness & Mass vs Internal Core Thickness

Increasing thickness of internal Core Elements results in minor stiffness increase.



# 4 m Stiffness & Mass vs Radius of Curvature

At 4 meter, Radius of Curvature has insignificant effect on Stiffness and Mass



# Parametric Trade Studies

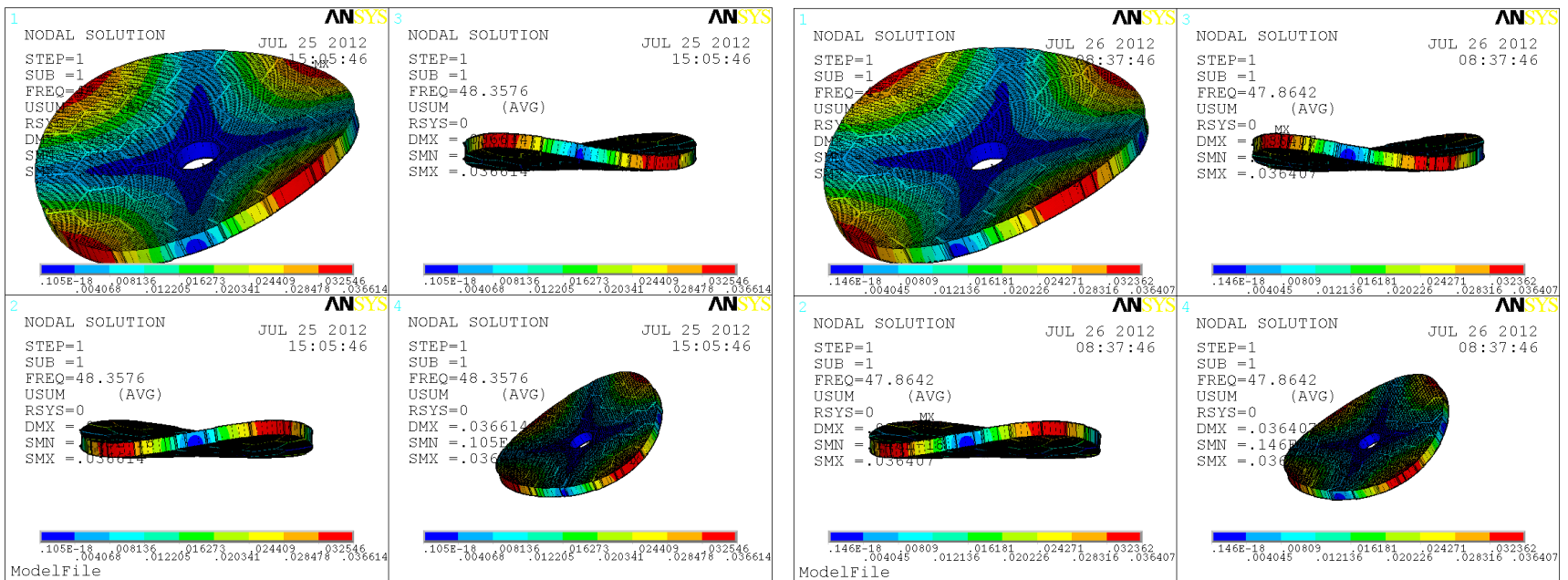
8 meter

# Symmetric vs. Offset

For a 8 meter, 500 mm thick mirror substrate, there is only minor differences between symmetric and off-set

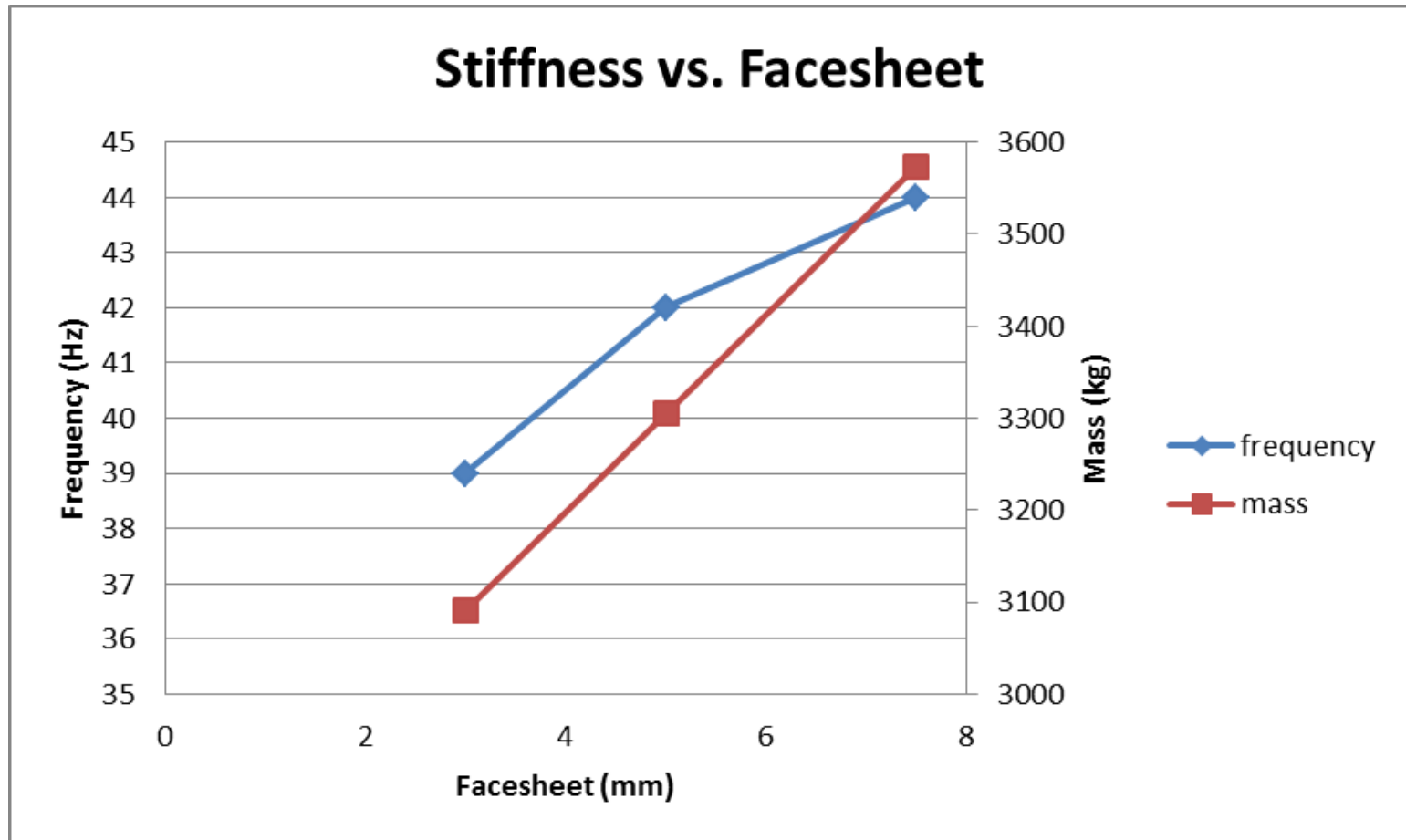
Symmetric (48.3 Hz)

Offset (47.9 Hz)



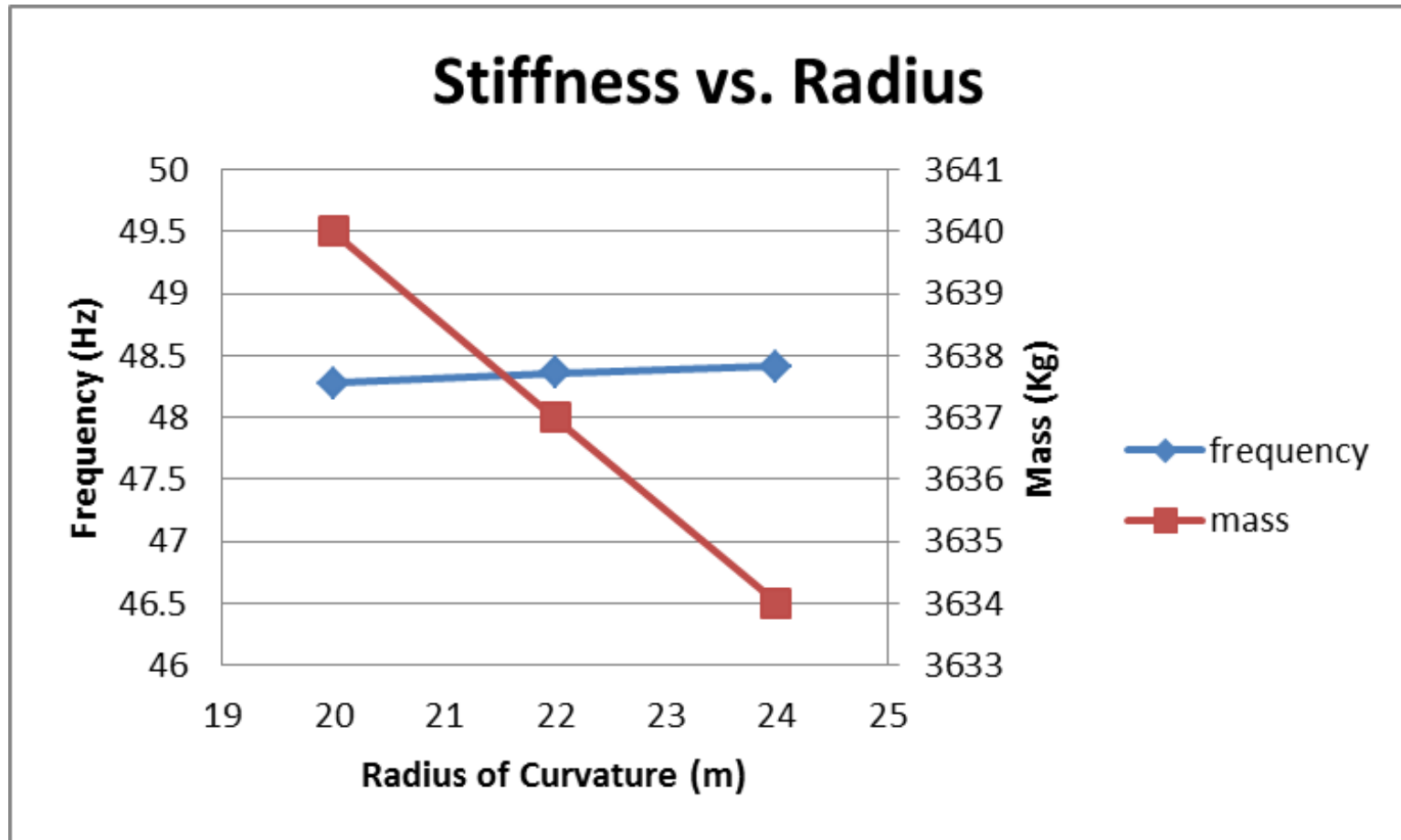
# 8 m Stiffness & Mass vs Facesheet Thickness

Increasing Facesheet thickness increases stiffness only to a point.



## 8 m Stiffness & Mass vs Radius of Curvature

At 8 meter, Radius of Curvature has an insignificant effect on Stiffness and Mass – plot is misleading mass change is 6 kg.



# Conclusion

We have used the Arnold Lightweight Mirror Modeler tool to generate 4 point designs and several parameter trade studies.

These trade studies allow one manipulate design architectural elements to maximize mirror stiffness for mass constraint.

Tool allows one to generate a complete model and analysis in less than 60 minutes



# Results Summary

4m Trade Study								
Architecture	Solid	Closed Back	Closed Back	Closed Back	Closed Back	Closed Back	Closed Back	Optimized
Mass	595 Kg	512 Kg	590 Kg	604 Kg	632 Kg	660 Kg	700 Kg	621 Kg
First Mode								
Frequency	8.2 Hz	101.4 Hz	115.0 Hz	117.5 Hz	120.9 Hz	122.9 Hz	136.3 Hz	124.5 Hz
Core Depth	N/A	30mm	40mm	40mm	40mm	40mm	50mm	40mm
Facesheet								
Thickness	22 mm	2.5 mm	2.5 mm	3 mm	4 mm	5 mm	2.5 mm	3 mm

8m Trade Study					
Architecture	Solid	Closed Back	Closed Back	Closed Back	Optimized
Mass	21801 Kg	3091 Kg	3305 Kg	3574 Kg	3637 Kg
First Mode					
Frequency	18.0 Hz	39.3 Hz	42.3 Hz	44.3 Hz	48.4 Hz
Core Depth	N/A	50 mm	50 mm	50 mm	50 mm
Facesheet					
Thickness	200 mm	3 mm	5 mm	7.5 mm	7 mm